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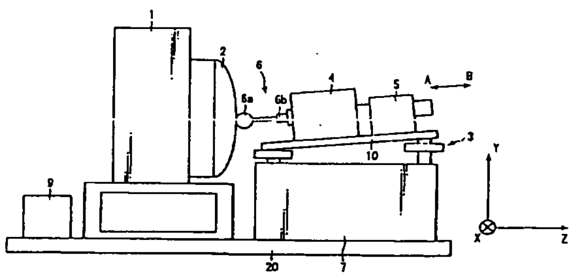

(57) Abstract: An apparatus for measuring a surface profile of an object to be measured, comprising a measuring probe (6) positioned to contact the surface of the object (2) to be measured, guide means (4) for supporting and guiding the measuring probe (6) in an axis direction of the measuring probe, tilt angle adjustment means (3) for tilting the guide means (4) at a predetermined tilt angle to a horizontal direction so that the measuring probe (6) contact the surface of the object (2) to be measured with a predetermined contact force, and drive means for relatively driving at least one of the measuring probe (6) and the object (2) to scan the surface of the object (2) to be measured with the measuring probe (6), the contact force being derived from a tilt direction component of the gravity of the measuring probe (6) generated when the measuring probe (6) is tilted.

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DESCRIPTION

APPARATUS FOR MEASURING A SURFACE PROFILE

Technical Field

The present invention relates to an apparatus for measuring a surface profile, which has a contact type measuring probe.

Background Art

For example, there is an apparatus disclosed in JPN. PAT. APPLN. KOKAI Publication No. 7-260471, as the conventional example of an apparatus for measuring the surface profile of a object to be measured. The conventional apparatus will be described below with reference to FIG. 12.

The above conventional apparatus comprises a measuring probe 41, an X-Z coordinate system driving section 42, a coordinate measuring section 43, an input means 44, and control means 45. More specifically, the measuring probe 41 includes a contact needle member 41a, which makes a contact an object to be measured 32 driven in a Y-axis direction by a Y-axis coordinate system driving section provided in a main body 30 of the above apparatus. In this case, the needle member 41a contacts the object 32 to be measured from above. The X-Z coordinate system driving section 42 drives the measuring probe 41 in the X and Z directions, and the

coordinate measuring section 43 measures the coordinates of the measuring probe 41. The input means 44 inputs tilt angle information of the contact needle member 41a at a contact measuring point with respect to a surface 32a to be measured. The control means 45 controls the measuring pressure of the measuring probe 41 on the surface of the object to be measured based on the tilt angle information inputted by the input means 44. In this case, the control means 45 controls the contact by the measuring probe 41 so that the sum of contact deformation of the measuring probe 41 and the object 32 to be measured becomes constant in the vertical direction to the surface to be measured 32a.

The conventional apparatus has the above structure, and the tilt angle information at the contact measuring point by the measuring probe 41 on the surface of the object to be measured is input from the input means 44. Based on the tilt angle information thus input, the apparatus can measure the surface profile of the measuring surface 32a of the object 32 to be measured while controlling the measuring pressure of the measuring probe 41 by the control means 45. As described above, the measuring pressure of the measuring probe 41 is controlled, and thereby, vertical contact deformation is always made constant with respect to the surface of the object to be measured. By doing so, it is possible to prevent

the generation of a measuring error resulting from changes of the contact deformation.

In the above conventional apparatus, a flat spring or a compression coil is used for controlling the measuring pressure so that the measuring pressure of the measuring probe 41 becomes extremely small, or the contact force always becomes constant on the surface of the object 32 to be measured.

When the conventional apparatus has the above structure, the measuring probe 41 contacts the surface of the object 32 to be measured at predetermined thrust. In particular, the measuring probe 41 must be held so that the thrust of the measuring probe 41 can be kept constant in all directions. In order to obtain such a stable thrust, it is necessary to greatly reduce the frictional resistance of each member or the hysteresis characteristics of springs.

Disclosure of Invention

Accordingly, it is an object of the present invention to provide an apparatus for measuring a surface profile, which can make constant the contact force at each point on the surface of an object to be measured, and can measure the surface profile with an extremely small contact force.

In order to achieve the above object, according to a first aspect of the present invention, there is provided an apparatus for measuring a surface profile

of an object to be measured, comprising:

a measuring probe positioned to contact the surface of the object to be measured;

guide means for supporting and guiding the measuring probe in an axis direction of the measuring probe;

tilt angle adjustment means for tilting the guide means at a predetermined tile angle to a horizontal direction so that the measuring probe contact the surface of the object to be measured with a predetermined contact force, and

drive means for relatively driving at least one of the measuring probe and the object to scan the surface of the object to be measured with the measuring probe,

the contact force being derived from a tilt direction component of the gravity of the measuring probe generated when the measuring probe is tilted.

Preferably, the tilt angle ranges from 0.0005 to 5°, more preferably from 0.03 to 0.2°. The contact force ranges from 5 to 300 mgf, more preferably from 30 to 90 mgf.

The apparatus has the above structure, and thereby, the contact force of the measuring probe applied to the surface of the object to be measured is derived from the tilt direction component of the gravity of the measuring probe. Therefore, there is no need to take the hysteresis characteristic into

consideration. A constant contact force is applied to each point on the surface of the object to be measured. Since the measuring probe is tilted at the predetermined tilt angle by the tilt angle adjustment means, an extremely small contact force can be very readily obtained. Since the extremely small contact force is obtained as described above, the apparatus is a contact type; nevertheless, it is possible to highly accurately measure the surface profile of the object to be measured. Further, it is possible to obtain effects similar to non-destructive measurement of the surface profile of the object to be measured with non-contact.

According to a second aspect of the present invention, there is provided an apparatus for measuring a surface profile of an object to be measured wherein the guide means movably supports the measuring probe, and comprises a guide mechanism to guide the measuring probe with a predetermined frictional force between the guide means and the measuring probe, the frictional force being smaller than the tilt direction component of the gravity of the measuring probe.

According to the present invention, means generating an extremely small frictional force, for example, a linear guide, preferably, an air slider is used as the guide means. By so doing, since an extremely small contact force is obtained, the apparatus is a contact type; nevertheless, it is

possible to highly accurately measure the surface profile of the object to be measured.

According to a third aspect of the present invention, there is provided an apparatus for measuring a surface profile of an object to be measured wherein the tilt angle adjustment means tilts both the measuring probe and the object to be measured at a predetermined tilt angle to the horizontal direction.

According to the present invention, since the tilt angle is applied to both the measuring probe and the object to be measured, when the object is measured, no angle difference is generated between the measuring probe and the object to be measured. Therefore, there is no need to correct the tilt angle, and the apparatus is a contact type; nevertheless, it is possible to highly accurately measure the surface profile of the object to be measured.

According to another aspect of the present invention, there is provided an apparatus for measuring a surface profile of an object to be measured wherein the object to be measured has a predetermined surface roughness Ry and scanning length ϕ, and when a predetermined contact force F_θ is applied at the maximum contact angle αmax by the measuring probe, the maximum velocity Vmax of the measuring probe scanning the surface of the object to be measured has a relationship expressed by the following equation:

$V_{max} \propto (F_\theta \cdot \phi)/(R_y \cdot \alpha_{max})$

According to the present invention, if the object to be measured is formed of a very soft material that is liable to damage when measuring, the contact force F_θ is made small, and thereby, the object can be measured with the small contact forces F_θ without being damaged. Conversely, if there is no possibility that the object to be measured will be damaged, the contact force F_θ is made large, and thereby, the maximum scanning velocity Vmax becomes large. As a result, it is possible to shorten the time for measuring the surface profile of the object to be measured.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

Brief Description of Drawings

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a view schematically showing an apparatus for measuring a surface profile according to a first embodiment of the present invention;

FIG. 2 is a partially enlarged view showing the state in which a contact needle member of a measuring probe contacts with the surface of an object to be measured at a predetermined tilt angle in the apparatus for measuring a surface profile according to the first embodiment of the present invention;

FIG. 3 is a partially enlarged perspective view showing the structure of measuring probe support means;

FIG. 4 is a view schematically showing a tilt angle adjustment means in the first embodiment;

FIG. 5 is a view schematically showing a first modification of the tilt angle adjustment means in the first embodiment;

FIG. 6 is a view schematically showing a second modification of the tilt angle adjustment means in the first embodiment;

FIG. 7 is a view schematically showing a third modification of the tilt angle adjustment means in the first embodiment;

FIG. 8 is a block diagram showing a control system of the apparatus for measuring a surface profile according to the present invention;

FIG. 9 is a partially enlarged top plan view showing the state in which the contact needle member of

the measuring probe contacts the object to be measured;

FIG. 10 is a view schematically showing an apparatus for measuring a surface profile according to a second embodiment of the present invention;

FIG. 11 is a view schematically showing an apparatus for measuring a surface profile according to a third embodiment of the present invention; and

FIG. 12 is a view schematically showing a conventional apparatus for measuring the surface profile of a object to be measured.

Best Mode for Carrying Out of the Invention

The embodiments of the present invention will be described below. In the following embodiments, the X-Y-Z axis orthogonal coordinate system shown in FIG. 1 is used in all embodiments of the present invention, and a negative direction of the Z-axis and a positive direction thereof are defined as the distal end side and the proximal end side, respectively.

(First embodiment)

In the first embodiment, the apparatus for measuring a surface profile has a flat base portion 20 as shown in FIG. 1. A support member 1 and a table portion 7 are fixed on the base portion 20. The table portion 7 is provided with a mount plate 10 via a tilt angle adjustment means 3. A guide means 4 is attached to the mount plate 10. An object 2 to be measured is supported by the support member 1. A measuring probe 6

is movably supported by the guide means 4 and positioned so as to contact the surface of the object 2 to be measured. First and second position-detecting elements 5 and 9 are provided on the mount plate 10 and the base portion 20, respectively.

In the first embodiment, the guide means 4 is an air slider. As illustrated in FIG. 3, the guide means 4 comprises a slider support member 4a and a slider movable member 4b. The slider support member 4a is formed with an opening. The slider movable member 4b penetrates movably the opening of the slider support member 4a, and is floatingly supported. The air slider 4 has an air supply section (not shown), which supplies air to a space 210 between the slider support member 4a and the slider movable member 4b. The space 210 is very narrow, and has a width of 100 µm or less, preferably 20 µm or less. The material of the air slider 4 is ceramic, a metallic material such as iron, or a glass material. The guide means 4 may be a linear guide.

The above measuring probe 6 comprises a cylinder- or prism-shaped trunk member 6b and a sphere- or wedge-shaped contact needle member 6a, which is attached to the distal end of the trunk member 6b. The trunk member 6b of the measuring probe 6 is attached to the slider movable member 4b of the guide means 4, and is movable in the directions of arrow A and B of FIG. 1

integrally with the slider movable member 4b. The contact needle member 6a is positioned so as to contact the surface of the object 2 to be measured.

In this case, the directions A and B shown in FIG. 1 are directions (hereinafter, referred to as tilt directions) tilted at a predetermined tilt angle θ (0 < θ < 90°) to the Z direction, as shown in FIG. 2, and are parallel to the axial direction of the measuring probe 6.

In the first embodiment, the first and second position-detecting elements 5 and 9 are optical scales or laser range finders. The first position-detecting element 5 is positioned so as to detect a tilt direction displacement l of the measuring probe 6. On the other hand, the second position-detecting element 9 is positioned so as to detect the X-axis direction position of the contact needle member 6a.

As schematically shown in FIG. 4, the above tilt angle adjustment means 3 comprises first and second angle adjustment members 3a and 3b. These angle adjustment members 3a and 3b are individually connected to the table portion 7 at their lower end portions by a screw. Either of the angle adjustment members 3a and 3b is rotatably supported on the mount plate 10 by a joint or a rotatable support member.

At least one of the angle adjustment members 3a and 3b has the following structure movable in the

forward and backward directions along arrows C and D parallel to the Y-axis direction so that the mount plate 10 can be tilted to the X-Z plane, that is, the measuring probe 6 can be tilted at a predetermined tilt angle to the Z axis. The above movement is made by mechanical means such as a screw, and may be made by electric means such as a motor. The angle adjustment members 3a and 3b are arranged at the distal and proximal end portions of the mount plate 10 at least one by one, and are operable independently of each other.

More specifically, the first angle adjustment member 3a rotatably supports the mount plate 10 by using a pivot. On the other hand, the second angle adjustment member 3b is provided with a wheel at the upper portion, and is formed with a screw at the lower portion. The second angle adjustment member 3b is adjusted by the screw, and thereby, changed in the Y-axis direction with respect to the table portion 7. In this case, the wheel rotates on the lower surface of the mount plate 10, and thereby, the second angle adjustment member 3b can freely move with respect to the mount plate 10. Therefore, the above two angle adjustment members 3a and 3b cooperate mutually so that the mount plate 10 can be tilted at the predetermined tilt angle. The mount plate 10 is kept in a state of being tilted at the above tilt angle by controlling the

screw.

In FIG. 5 to FIG. 7, there are shown modifications of the tilt angle adjustment means 3. In the first modification shown in FIG. 5, the distal side first angle adjustment member 3a of FIG. 4 comprises a pivotal member 211 having its center axis parallel with the X-axis and a circular cross section. For example, the pivotal member 211 is a rotatably supportable member such as a cylindrical or spherical member. The second angle adjustment member 3b comprises a tilt member 212 having a triangular prism. In this case, the tilt member 212 is inserted with its bevel being oriented to the mount plate 10.

The above two members 211 and 212 cooperate mutually so that the distal side of the mount plate 10 can be made lower than the proximal side thereof. More specifically, the mount plate 10 is supported to move along the bevel of the tilt member 212 so that it can be rotated in the direction of arrow E about the pivotal member 211.

In the first modification shown in FIG. 5, in order to change the tilt angle, the tilt member 212 is moved in the direction of arrow F. The tilt member 212 is fixed by a fixing member (not shown), and thereby the mount plate 10 is kept in a state being tilted at the predetermined angle.

In the second modification shown in FIG. 6, the

distal side pivotal member 211 of FIG. 5 comprises a plate-shaped elastic member 213 connected to the mount plate 10 and the table portion 7. The elastic member 213 is a flat spring or the like, for example. A proximal side angle adjustment member 214 may be either the above angle adjustment member 3a or the above tilt member 212. In either case, the mount plate 10 is connected or supported to the proximal side angle adjustment member 214 so that it can be rotated in the direction of arrow G about the plate-shaped elastic member 213.

In the second modification shown in FIG. 6, the operation for changing the tilt angle is basically the same as for the tilt angle adjustment means shown in FIG. 4 or FIG. 5. A tension member (not shown) is interposed on the distal side between the table portion 7 and the mount plate 10, and/or a thrust member (not shown) is interposed on the proximal side therebetween, and thereby, the mount plate 10 is kept in a state of being tilted at the tilt angle.

In the third modification shown in FIG. 7, the tilt angle adjustment means 3 comprises a tilt-generating member 215 having a circumferential or spherical surface, and a recess portion. The recess portion has a shape complementary to the circumferential or spherical surface of the tilt-generating member 215, and is formed on the upper